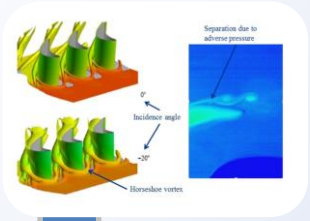
https://ntrs.nasa.gov/search.jsp?R=20160009221 2020-03-11T00:07:23+00:00Z

APPLICATION OF PINNIPED VIBRISSAE TO AEROPROPULSION

ASME Turbo Expo 2015
GT2015-43055

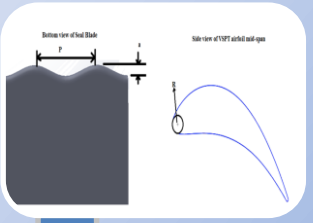
PI: Vikram Shyam
Team: Ali Ameri, Phil Poinsatte, Doug Thurman, Adam Wroblewski, Chris Snyder

Outline

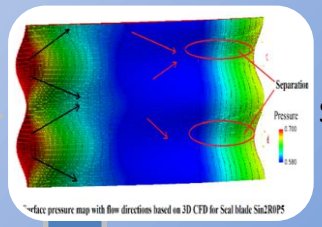


Motivation

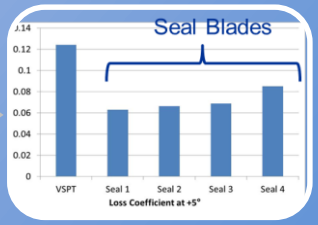
Background



Extraction and Application

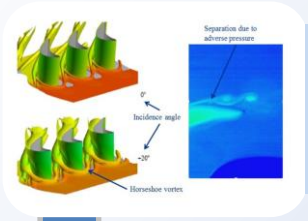


Simulation and Testing



Results and Conclusions

Outline



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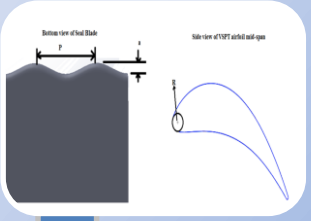

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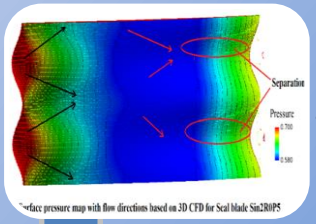

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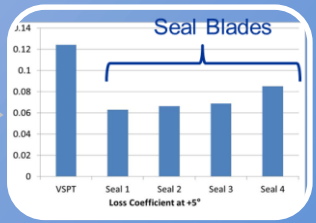
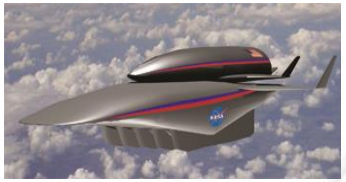


Results and Conclusions

NASA Aeronautics Programs



Fundamental Aeronautics Program

Conduct fundamental research that will produce innovative concepts, tools, and technologies to enable revolutionary changes for vehicles that fly in all speed regimes.

Integrated Systems Research Program

Conduct research at an integrated system-level on promising concepts and technologies and explore/assess/demonstrate the benefits in a relevant environment

Airspace Systems Program

Directly address the fundamental ATM research needs for NextGen by developing revolutionary concepts, capabilities, and technologies that will enable significant increases in the capacity, efficiency and flexibility of the NAS.

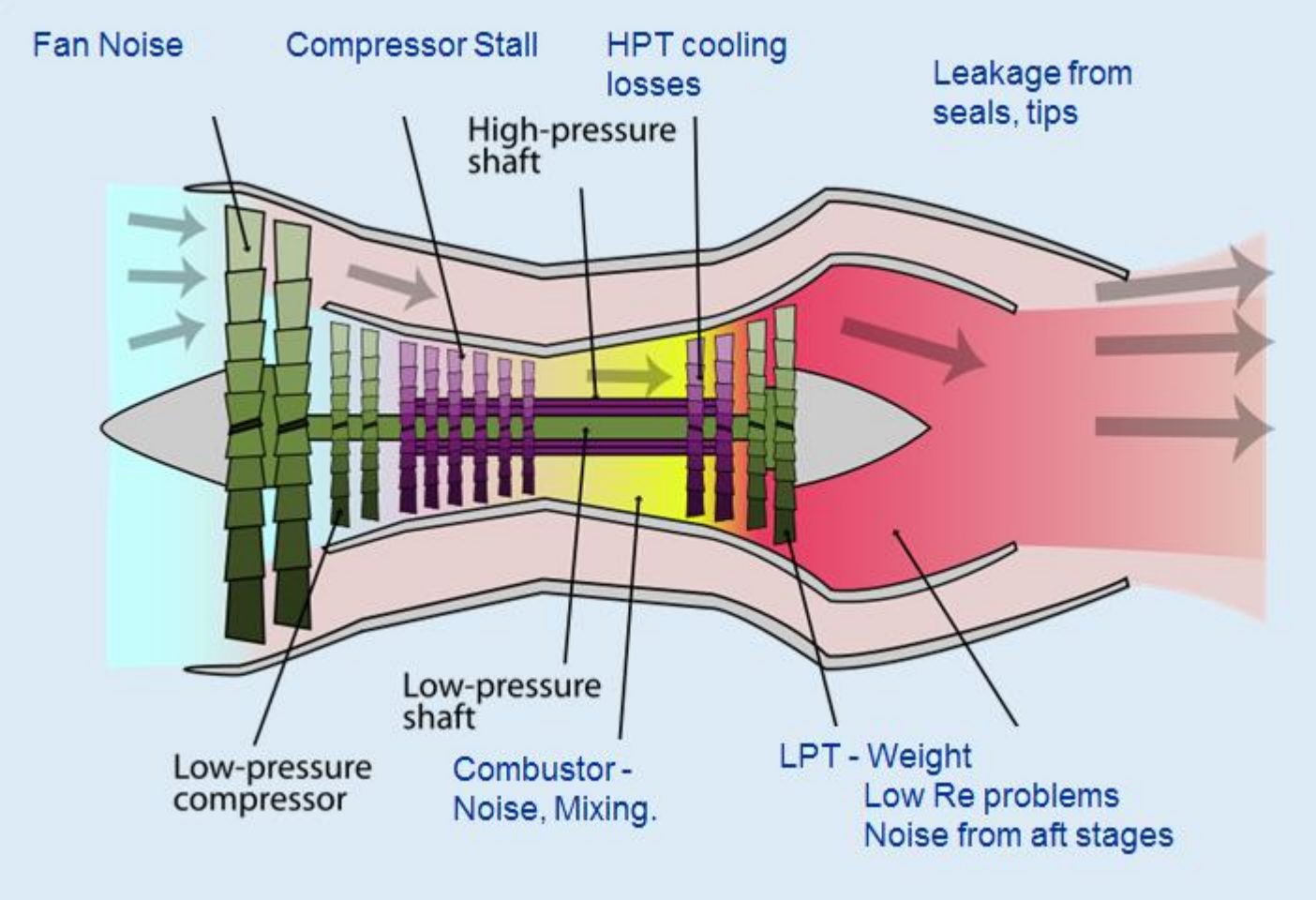
Aviation Safety Program

Conduct cutting-edge research that will produce innovative concepts, tools, and technologies to improve the intrinsic safety attributes of current and future aircraft.

Aeronautics Test Program

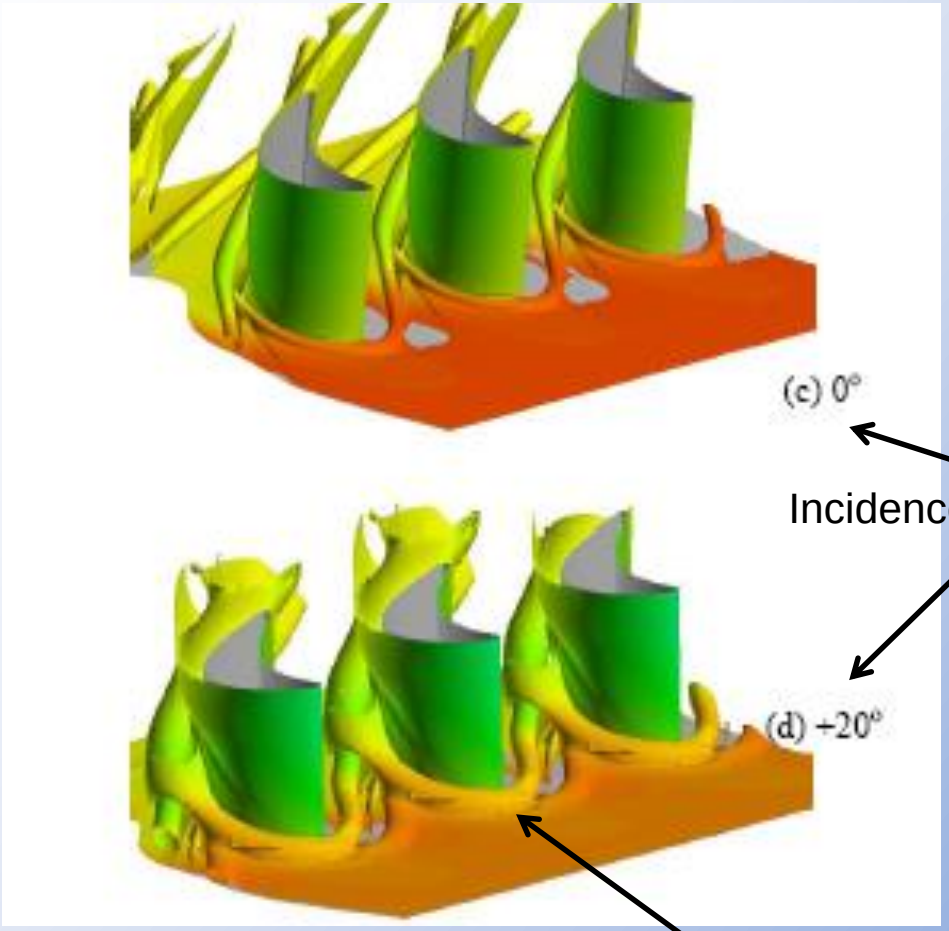
Preserve and promote the testing capabilities of one of the United States' largest, most versatile and comprehensive set of flight and ground-based research facilities.

Engine Performance Hits



http://en.wikipedia.org/wiki/File:Turbofan_operation_lbp.svg

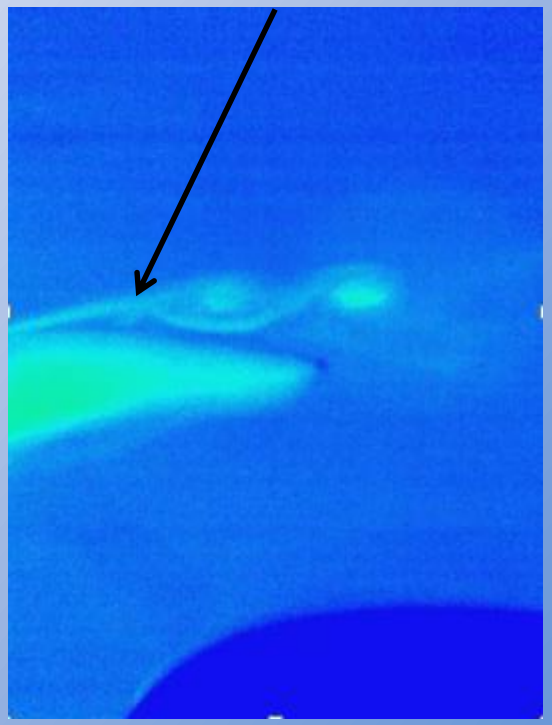
Incidence, Low Reynolds Number Challenges



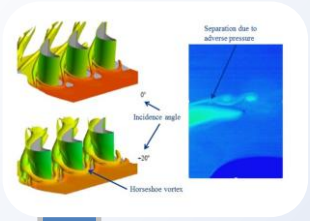
Incidence angle

Horseshoe vortex

Separation due to adverse pressure



Outline



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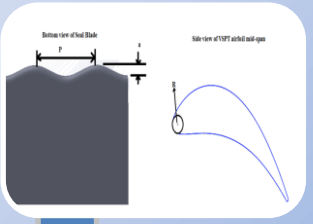

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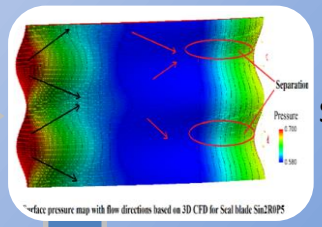

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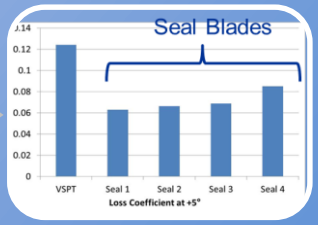
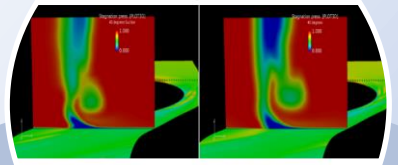
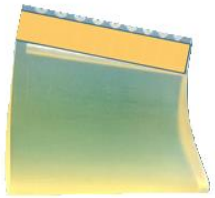


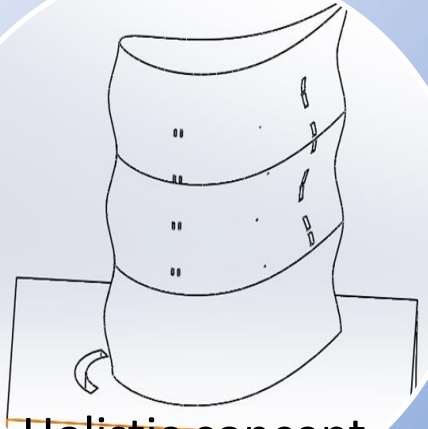
Results and Conclusions



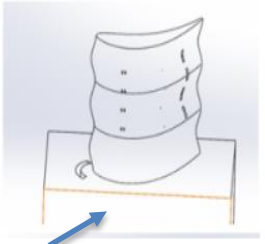
Slot upstream of Leading edge at the hub for suction



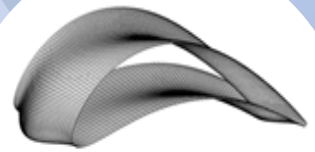
Trailing edge slots with spanwise pulsing (adjacent slots pulse out of phase)



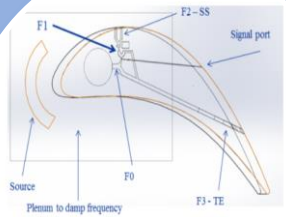
Holistic concept



Plenum to remove incoming signals



Seal Blade for operability, acoustics



Fluidic network to direct traffic and manage frequency content

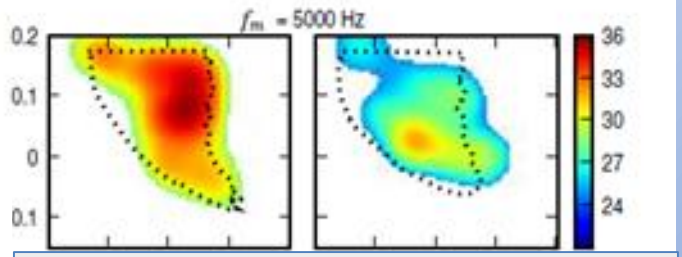
Shyam V., Ameri A., Poinsatte P., Thurman D., Wroblewski A., Snyder C., Culley D., Raghu S., "Holistic Aeropropulsion Concepts", NARI Seedling Fund Phase 1 final report, http://nari.arc.nasa.gov/sites/default/files/Shyam_Holistic%20Concepts_Final%20Report%20for%20FY13%2054%2022_single_column_v3_0.pdf

Alternative Approaches

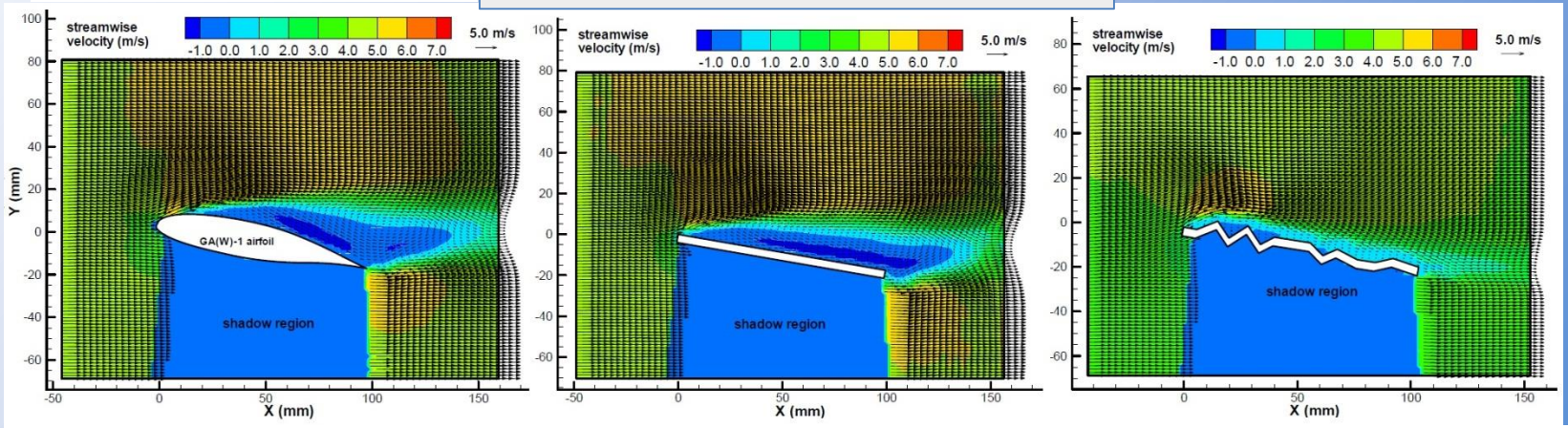
- Flow control
  - Requires power
  - Local effects that could be detrimental elsewhere
  - Cannot adjust to changing environment
  - VGJs (Vortex generating jets) extensively researched
  - Blowing into BL is common
- Design compromise by averaging over mission
- Noise reduction by blowing into wake costs 5% compressor bleed – unacceptable

Bio-inspired Approaches

Fish et al., “The Tubercles on Humpback Whales’ Flippers: Application of Bio-Inspired Technology” .



Geyer et al., “Silent Owl Flight, Experiments in the Aeroacoustic Wind Tunnel”



Tamai et al., “Aerodynamic Performance of a Corrugated Dragonfly Airfoil Compared with Smooth Airfoils at Low Reynolds Numbers”

Harbor Seal

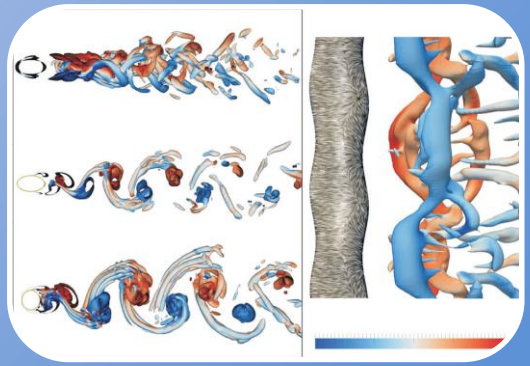
- "Harbor seals use their whiskers to analyze water movements (hydrodynamic trail following).
- This structure effectively changes the vortex street behind the whiskers and reduces the vibrations that would otherwise be induced by the shedding of vortices from the whiskers (vortex-induced vibrations)."
  – Hanke et al (2010)

Hypothesis: Whiskers must have some degree of incidence tolerance to enable detection of prey proximity and direction

Harbor Seal

Seal swimming

Whisker samples



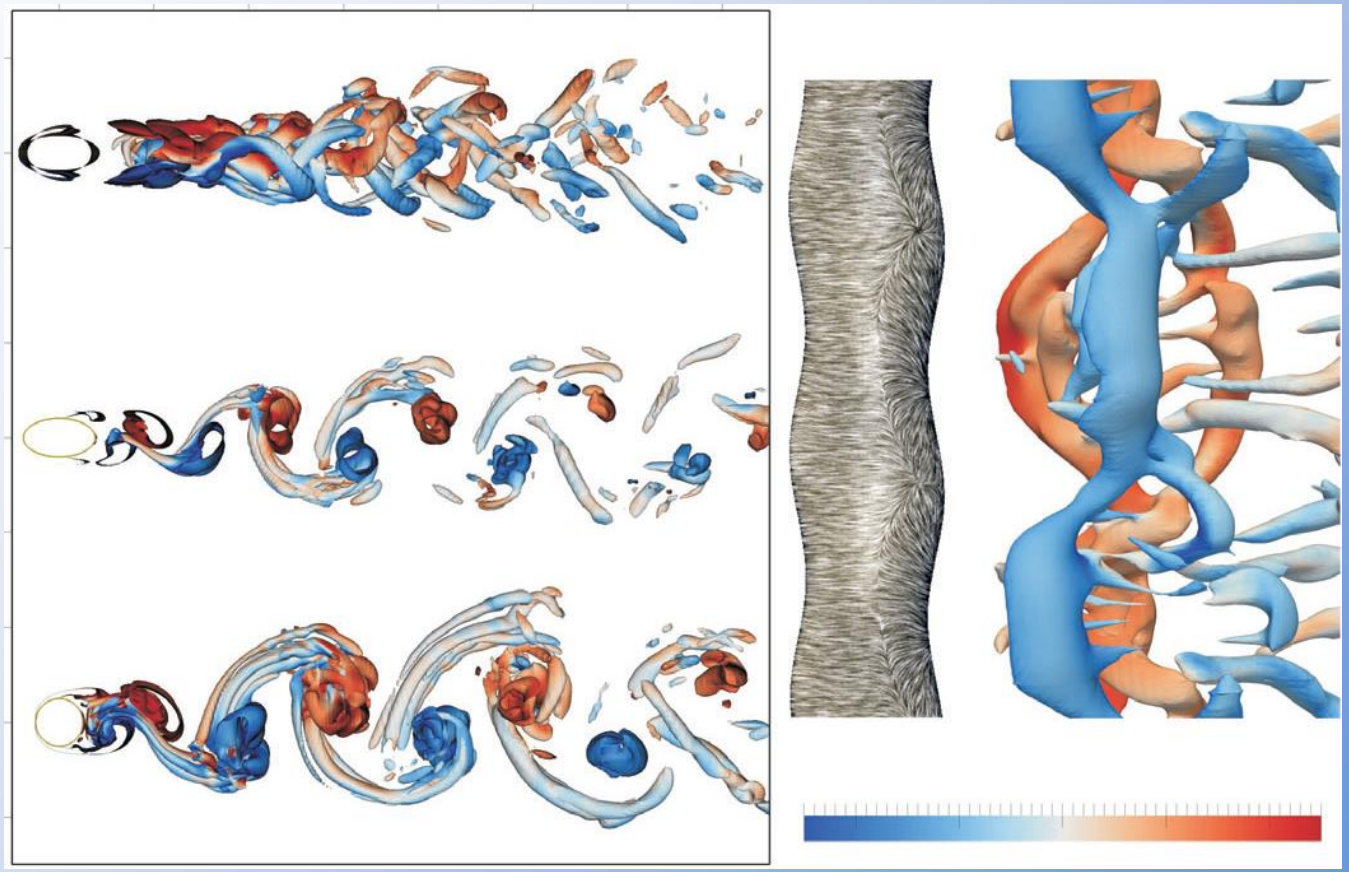
VIV results from Witte et al. (2012)

Harbor Seal

Seal whisker

Ellipse

Cylinder

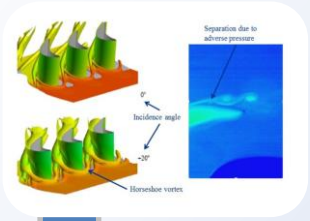


Re = 500

PIV on vibrissae at U of Rostock. Witte et al. 2012. Figure shows Q-criterion

- 40% mean drag coefficient reduction over cylinder
- 90% reduction of unsteadiness

Outline



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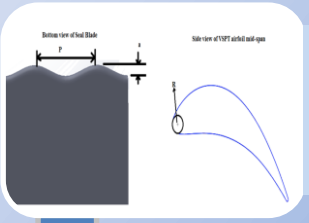
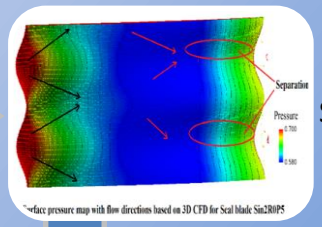


Extraction and Application



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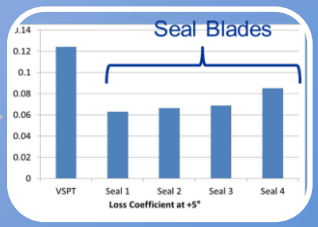


Results and Conclusions

- Create span-wise pressure gradient on suction side using span-wise undulations
- Push adverse gradient to valleys near trailing edge

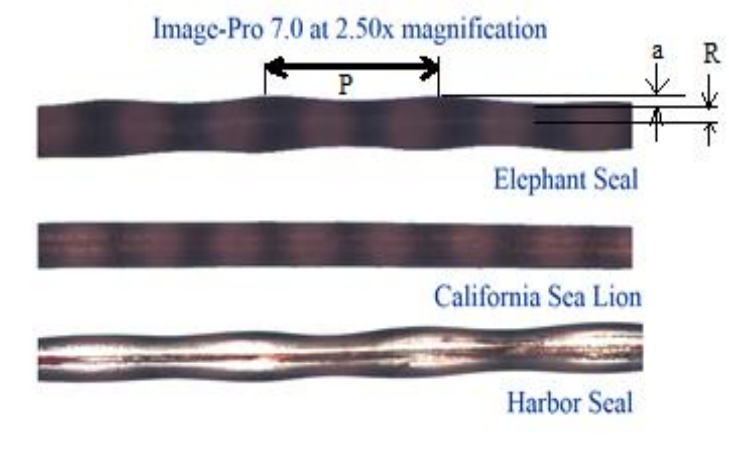


Figure 4. Scans of Pinniped vibrissae using optical microscope showing vibrissae parameters

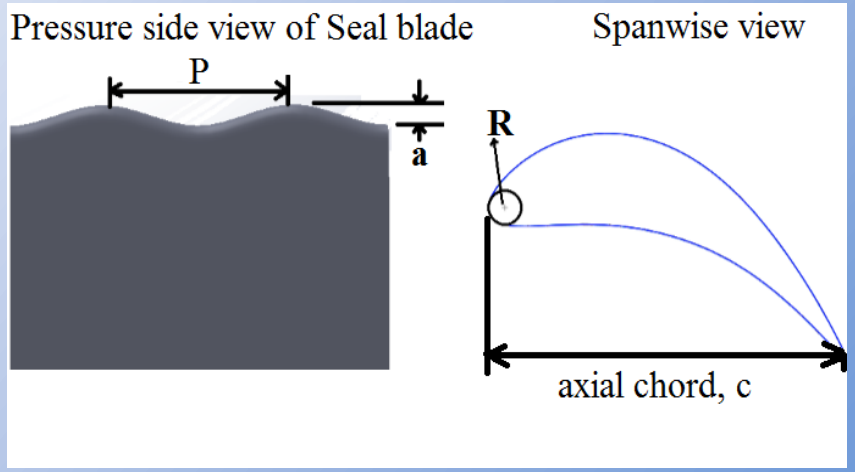
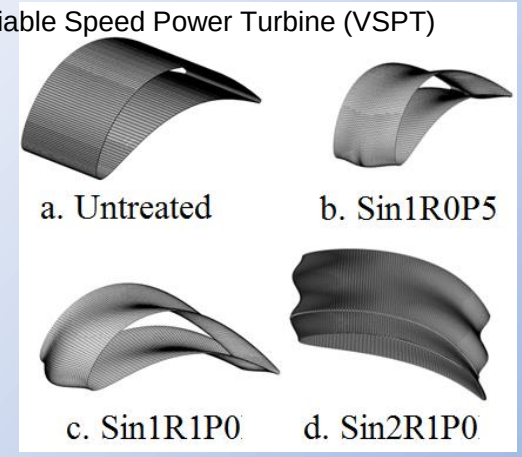


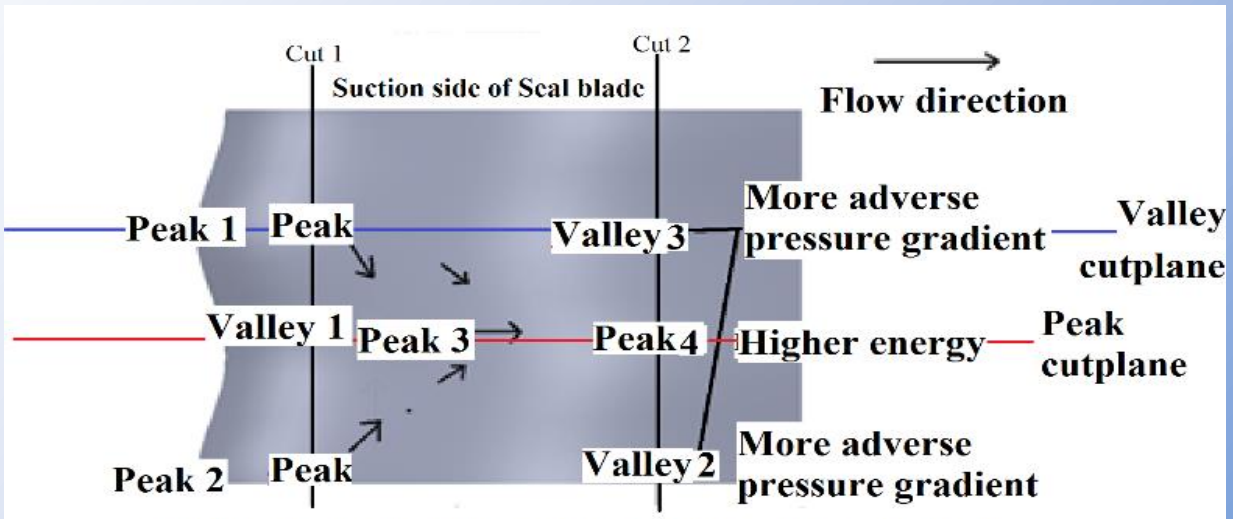
Figure 5. Parameters of undulations for the 'Seal Blade'

Variable Speed Power Turbine (VSPT)

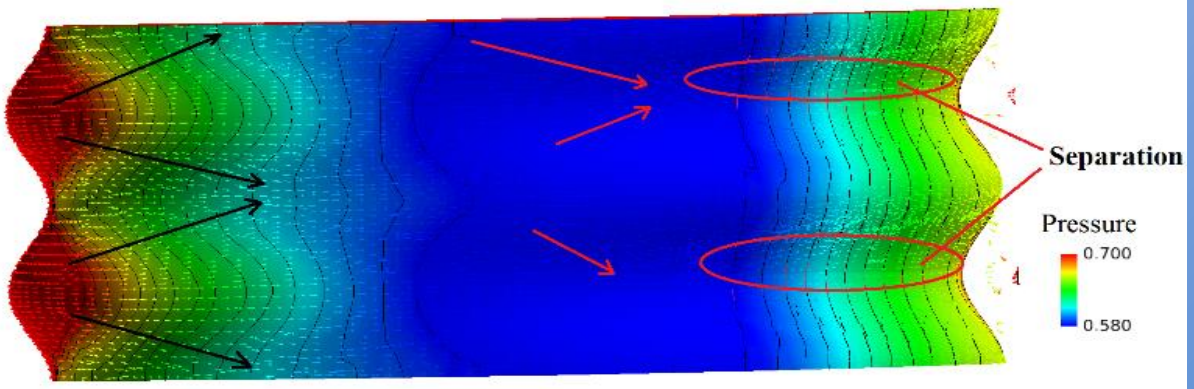


Parameters	Seal	Sin1R0P5	Sin1R1P0	Sin2R0P5	Sin2R1P0
Reference Radius, R	0.54	0.46	0.46	0.46	0.46
Peak to Peak, P	1.82	1.55	1.55	3.00	3.00
LE amplitude, a	0.12	0.12	0.23	0.12	0.23
ratio R/P	0.29	0.30	0.30	0.15	0.15
ratio a/P	0.07	0.07	0.15	0.04	0.08

- Trailing edge valleys occur at span-wise location of leading edge peaks
- Peaks transition to valleys at crown location

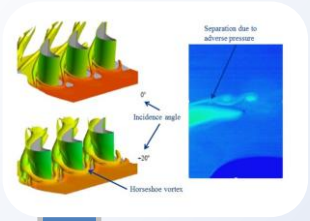


a. Preliminary concept showing notional velocity vectors on a Seal blade



b. Surface pressure map with flow directions based on 3D CFD for Seal blade Sin2R0P5

Outline



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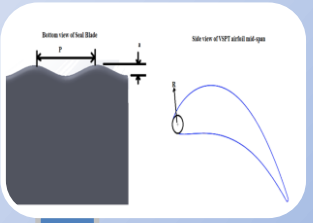

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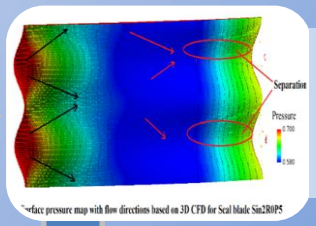

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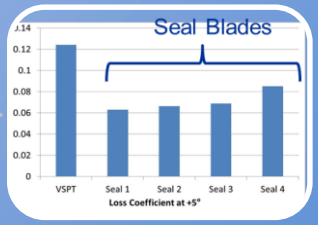


Results and Conclusions

Feasibility Study of Biomimetic Concept

Water table visualization

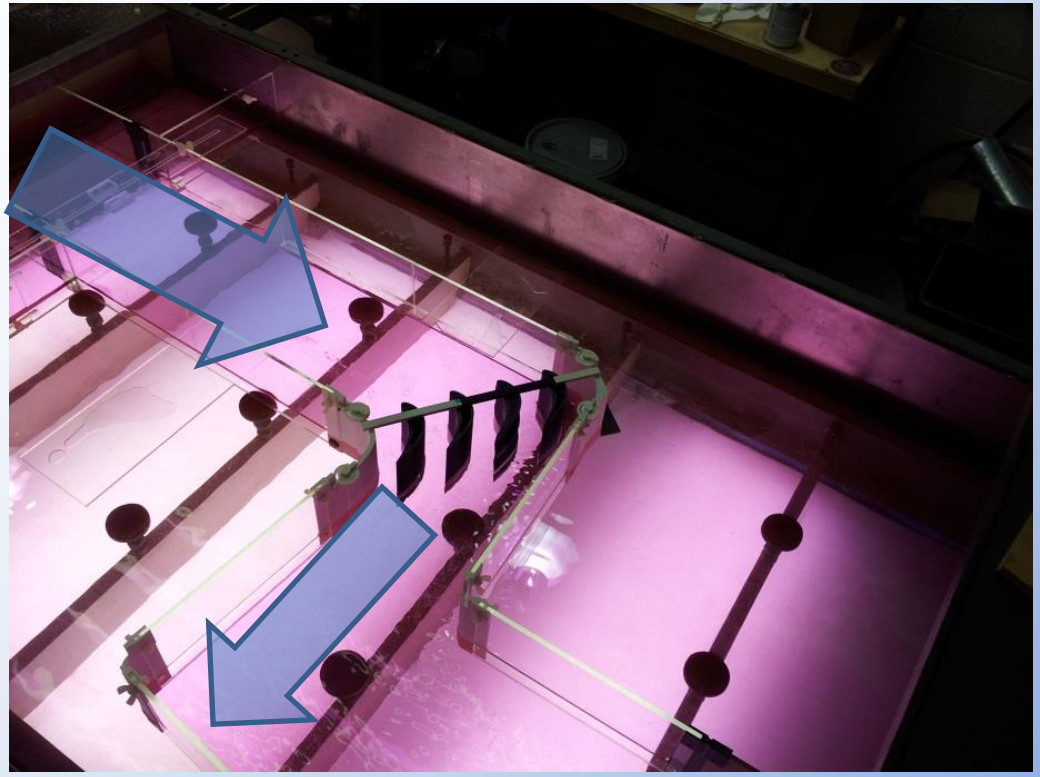
- CFD qualitative validation

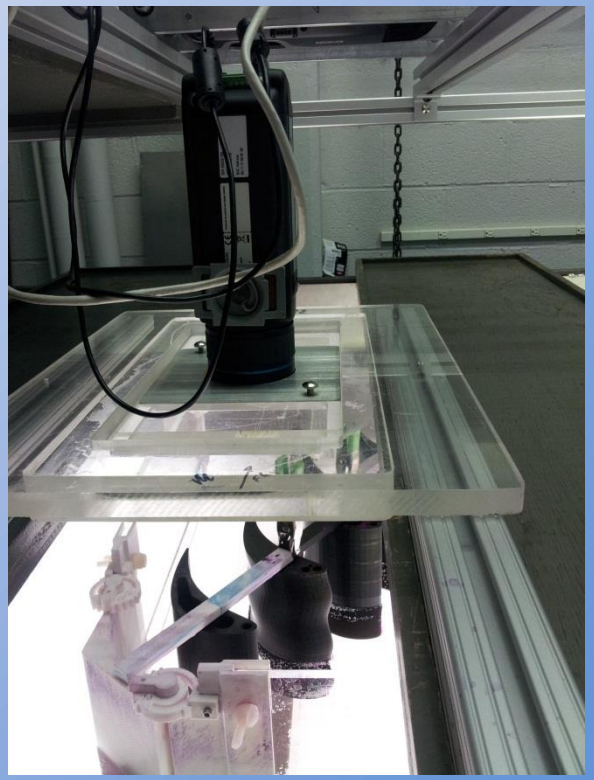
Unsteady 3D CFD using Glenn-HT

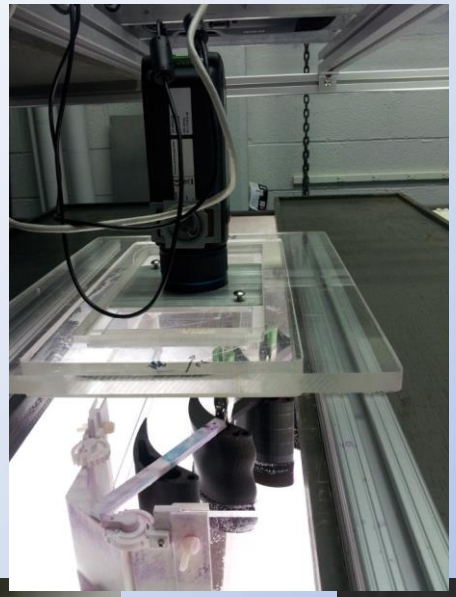
- Cp distribution at various span-wise locations
- Average wake pressure-loss coefficient 10% chord downstream of TE
- Multiple incidence angles

Wind Tunnel Testing

- SW2 cascade facility
  - Total pressure surveys at 10% chord downstream of TE
  - Hotwire surveys at 10% chord downstream of TE
  - Multiple incidence angles



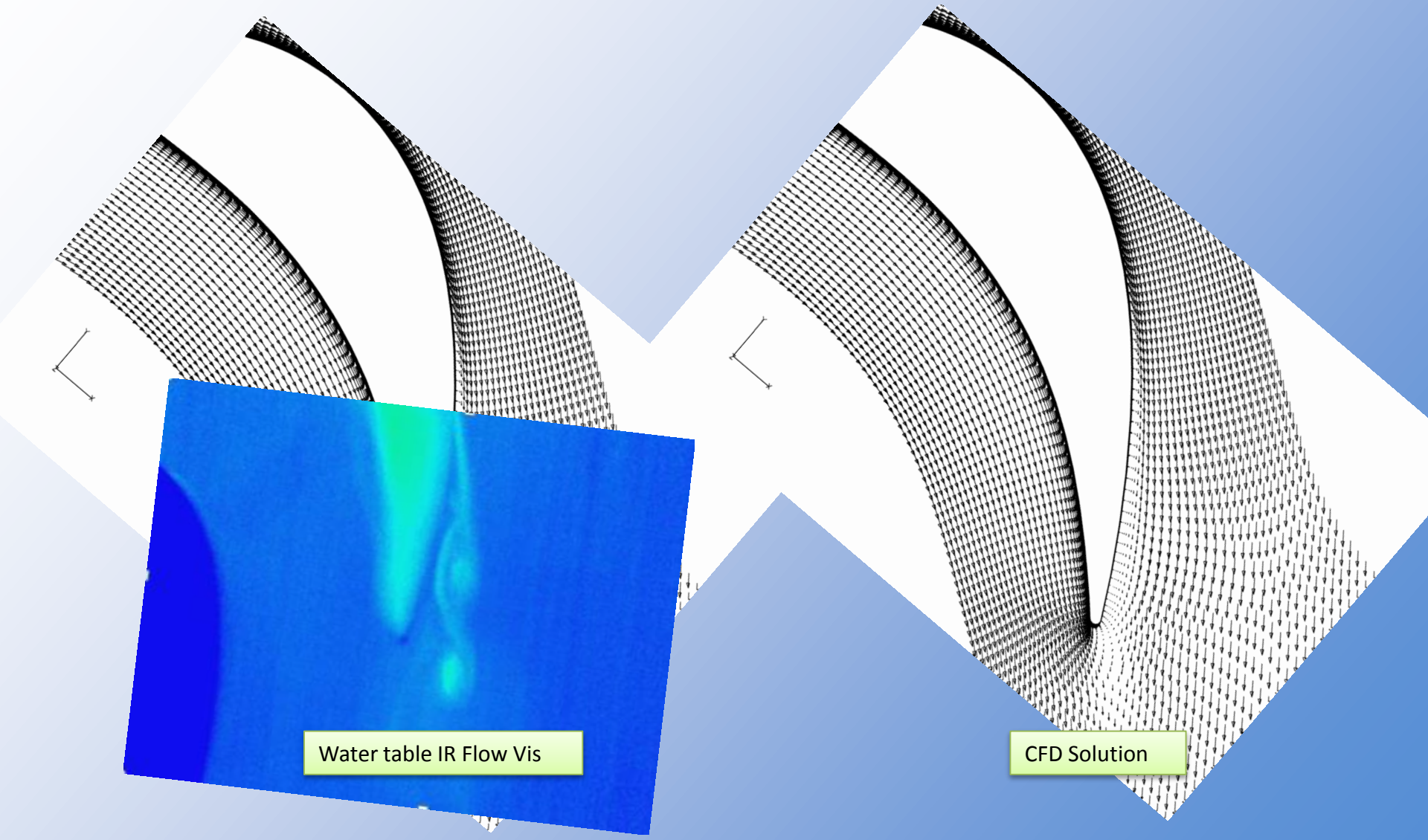


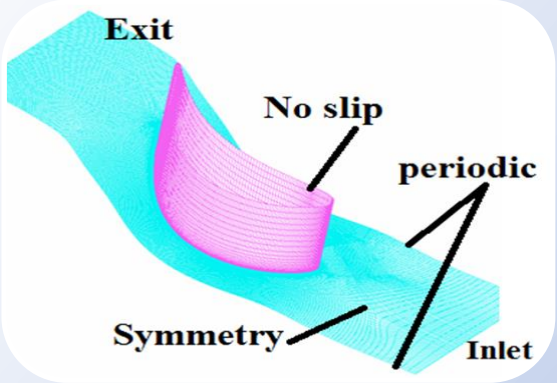


VSPT – 0 incidence

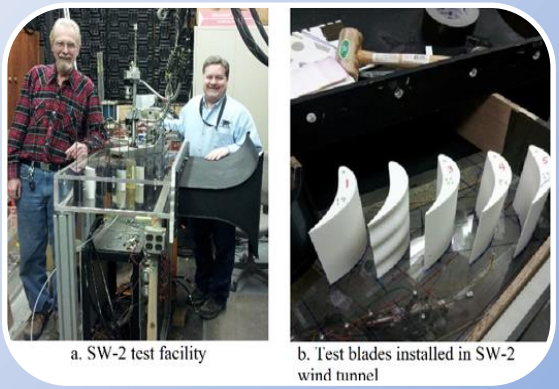
Seal Blade – 0 incidence

CFD Qualitative Validation



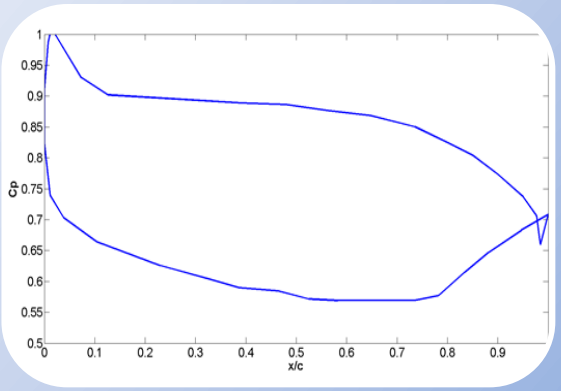


CFD setup

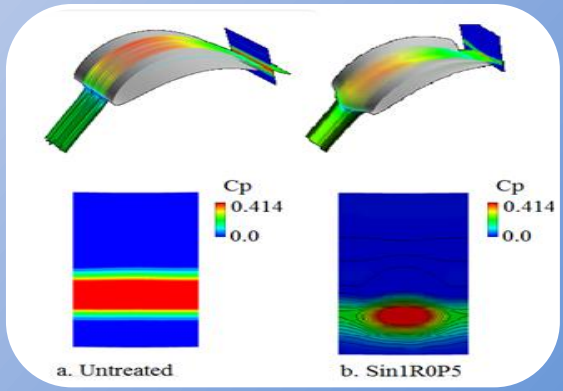


Wind tunnel SW-2

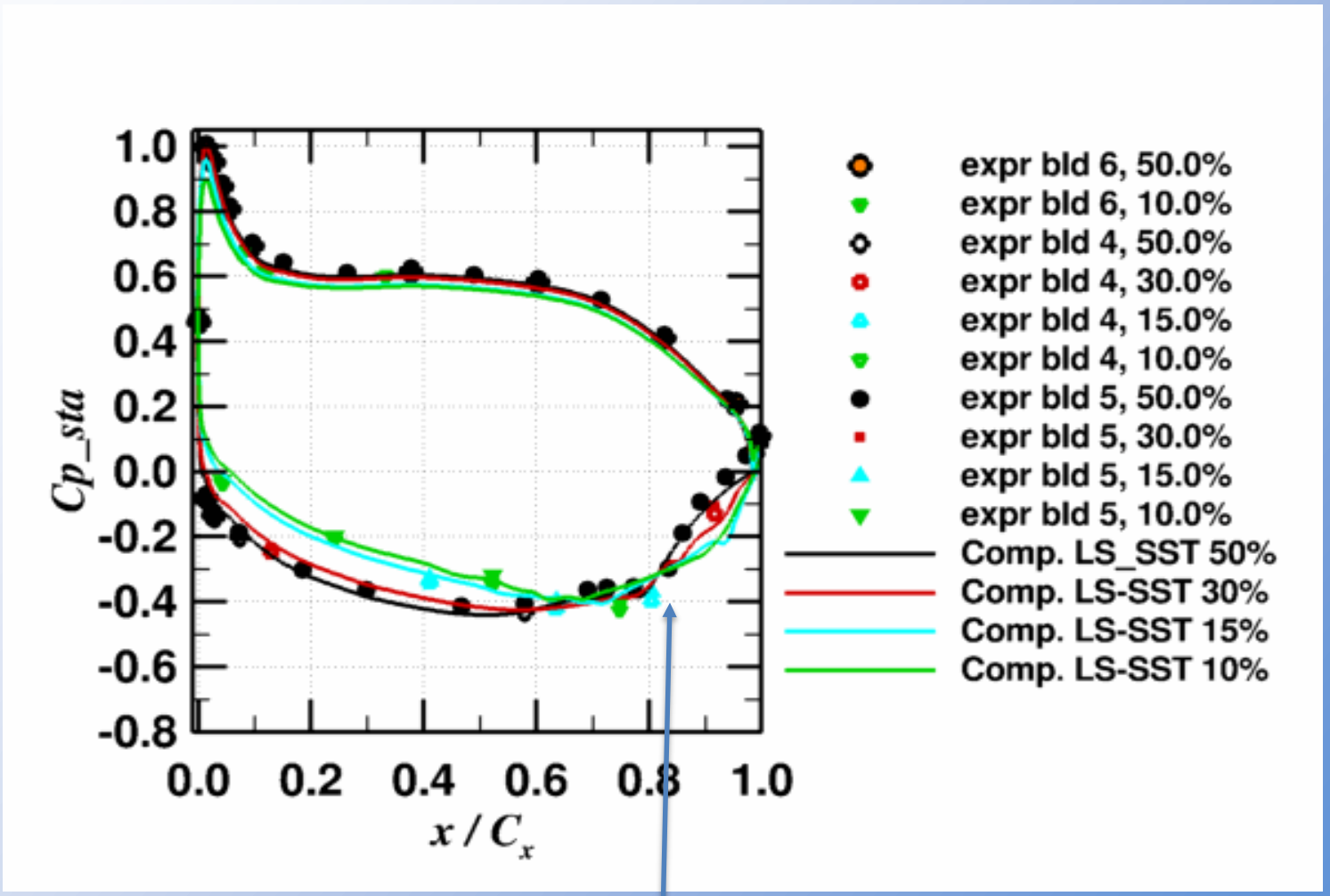
Low inlet turbulence ~ 4%,
Re = 100,000



Pressure profiles - CFD



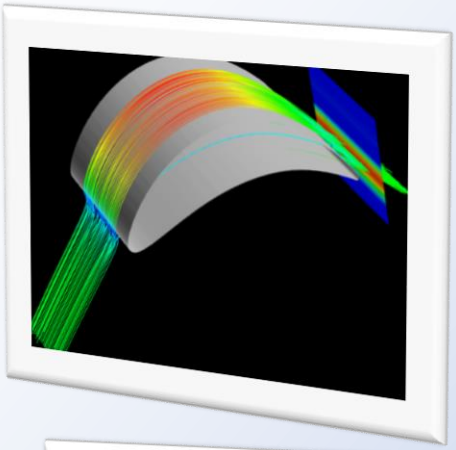
Blade pressure distribution – CFD and experiment

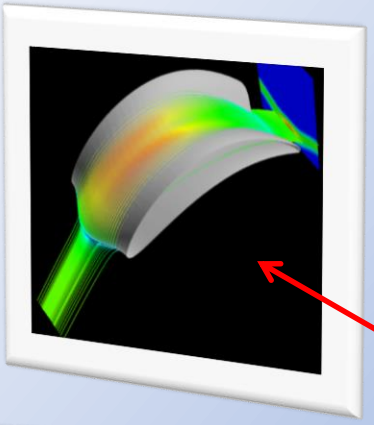


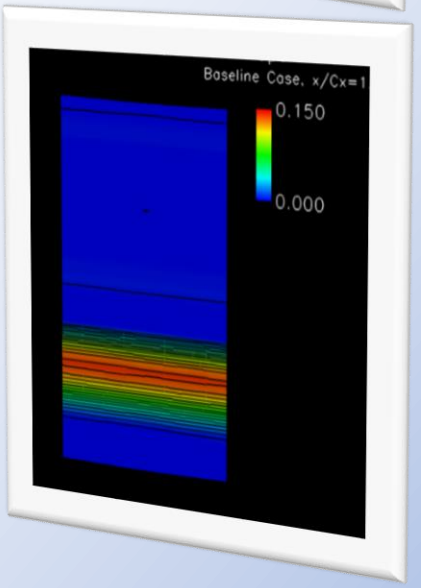
Separation captured by CFD (black line)

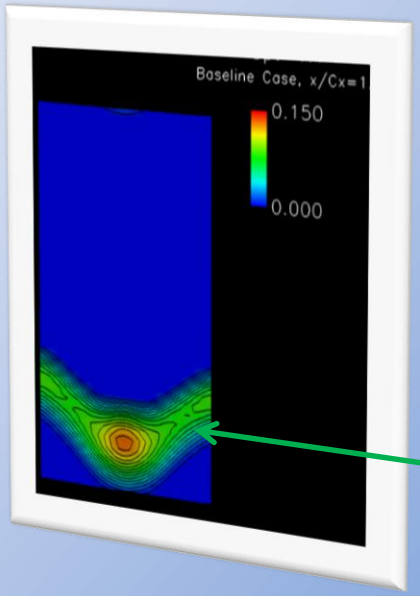
Untreated

Seal Blade

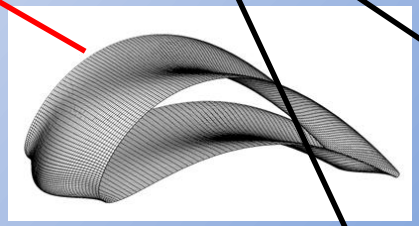


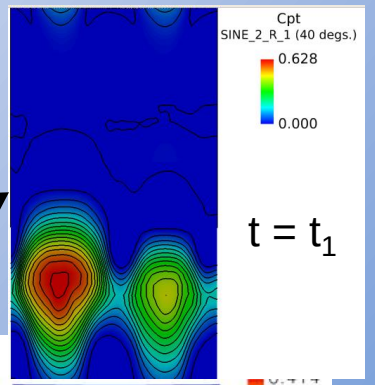


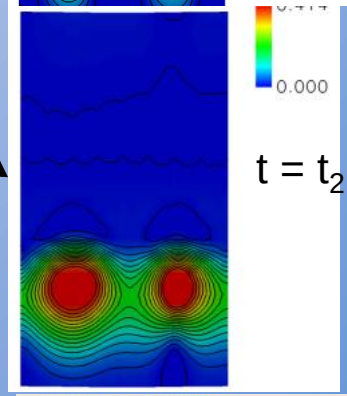


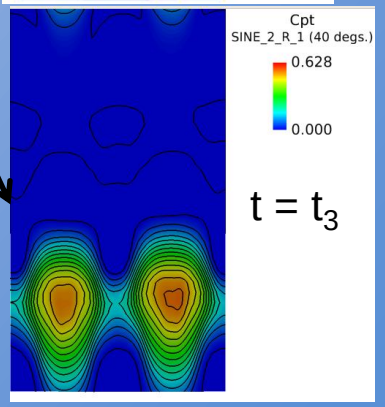


Noise reduction through wake control



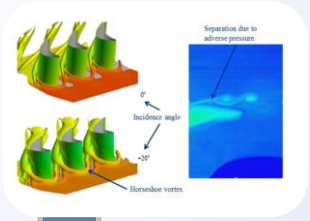






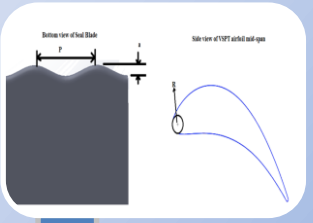
Fuel burn reduction due to elimination of separation

Outline

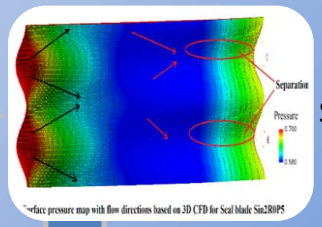


Motivation

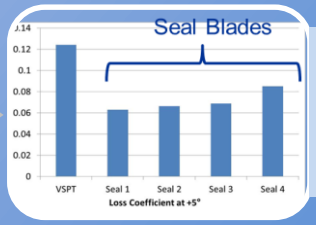
Background



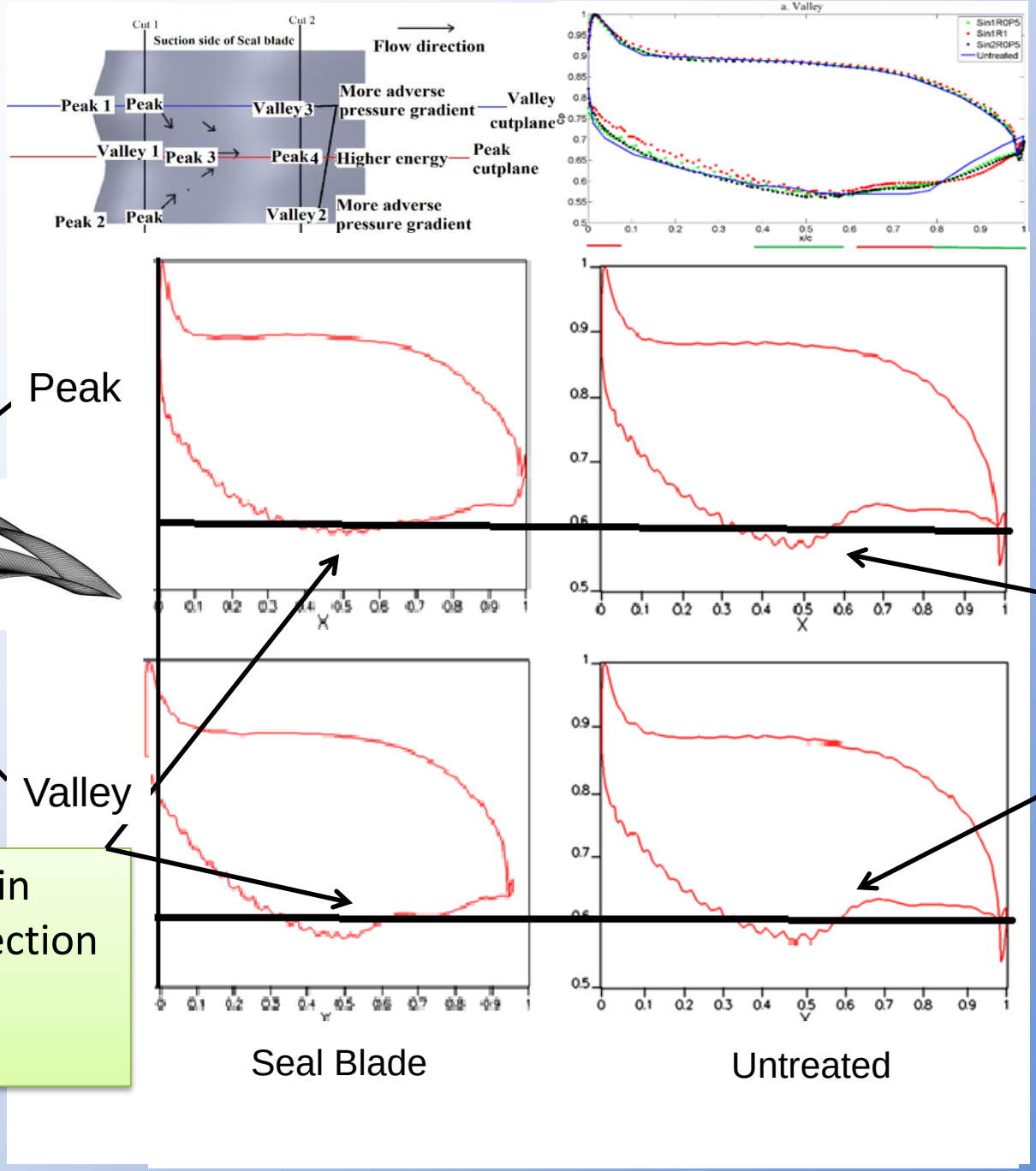
Extraction and Application



Simulation and Testing



Results and Conclusions



Shifts loading in span-wise direction to prevent separation.

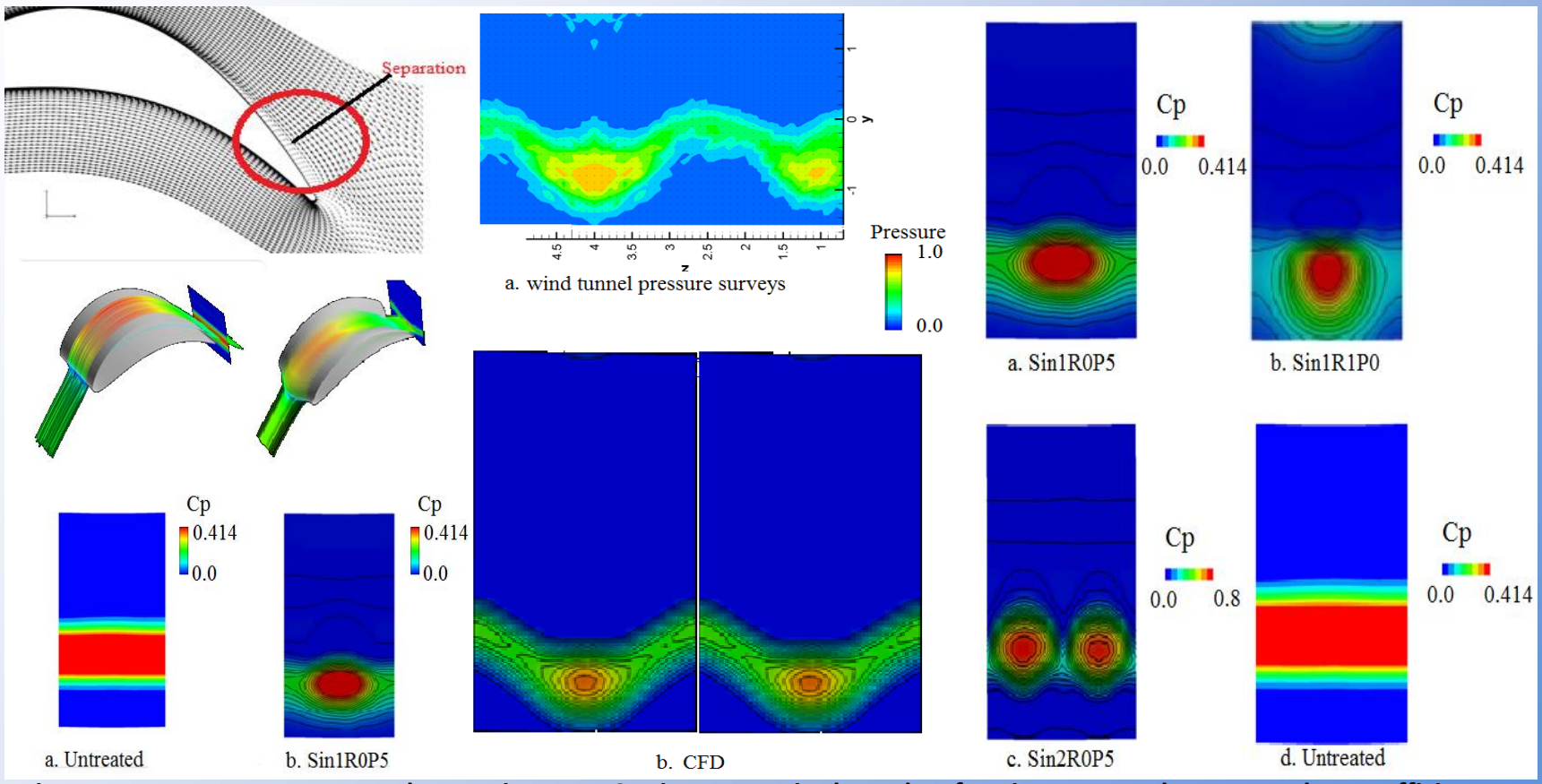


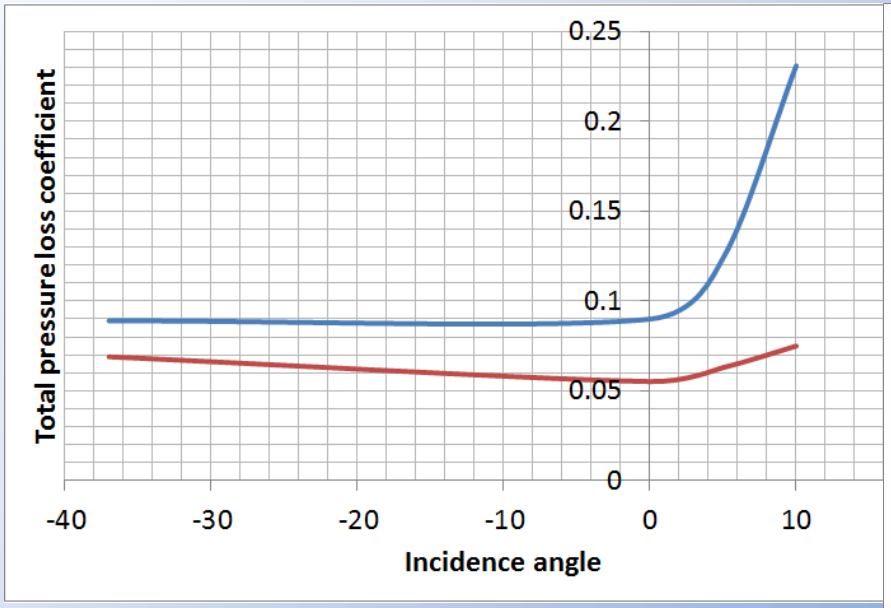
Figure 14. Bottom - pressure loss coefficient for a. Untreated blade and b. Sin1R0P5 Seal blade at +5° incidence angle. Top – Relative location of planes at x/c = 1.1.

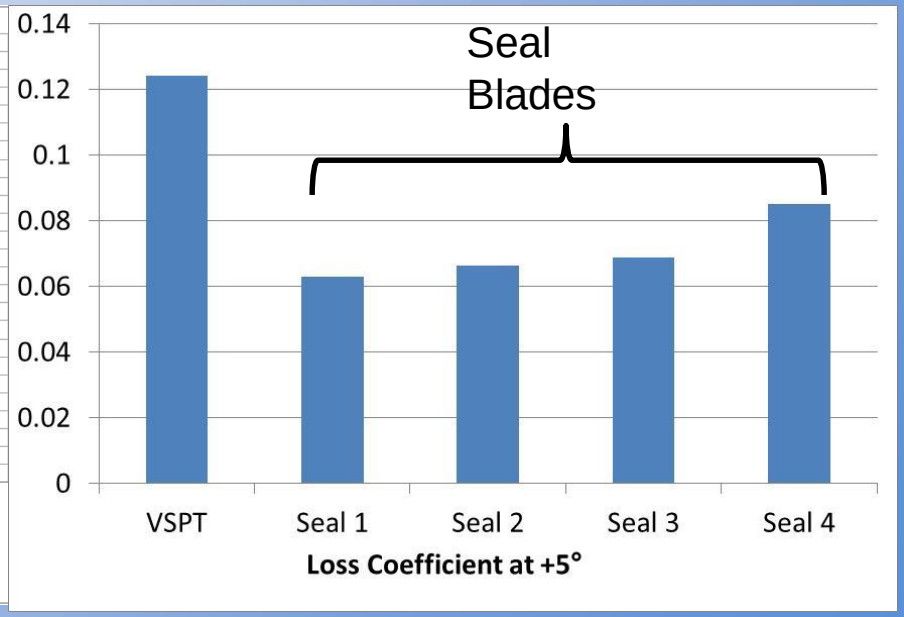
Figure 15. Static pressure in the wake of Sin1R0P5 Seal blade obtained from a. Wind tunnel total pressure survey of the wake at x/c = 1.1 and b. CFD simulation at +5° incidence angle

Figure 17. Wake pressure loss coefficients for Seal blades compared to Untreated blade.

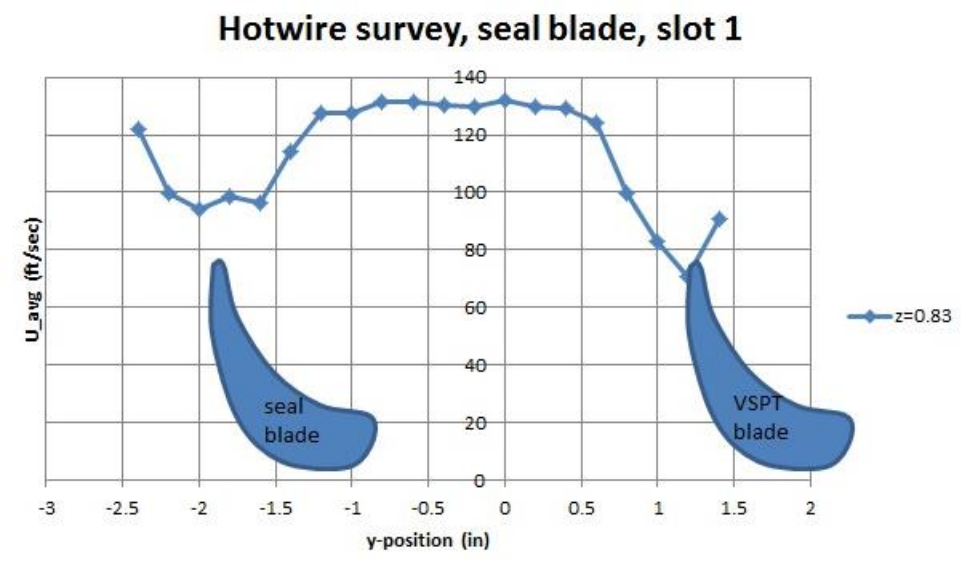
Incidence tolerance over wide range leads to fuel burn reduction

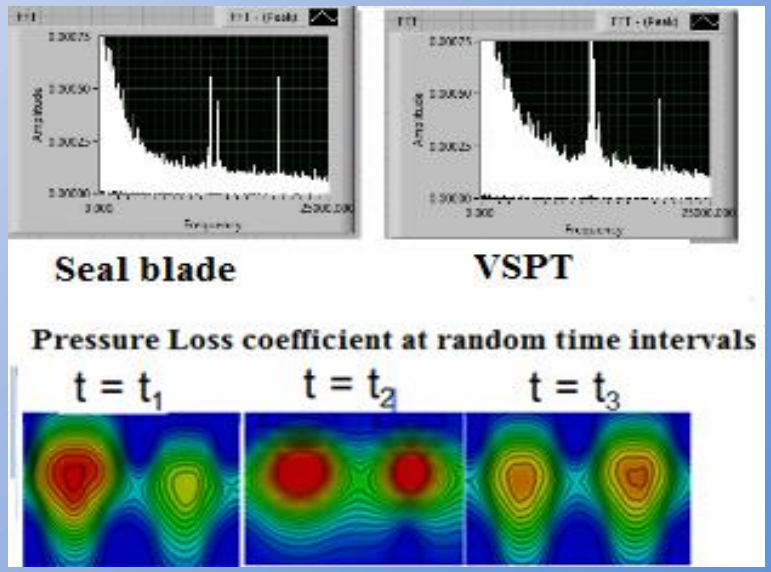
50% improvement in pressure recovery leads to fuel burn reduction



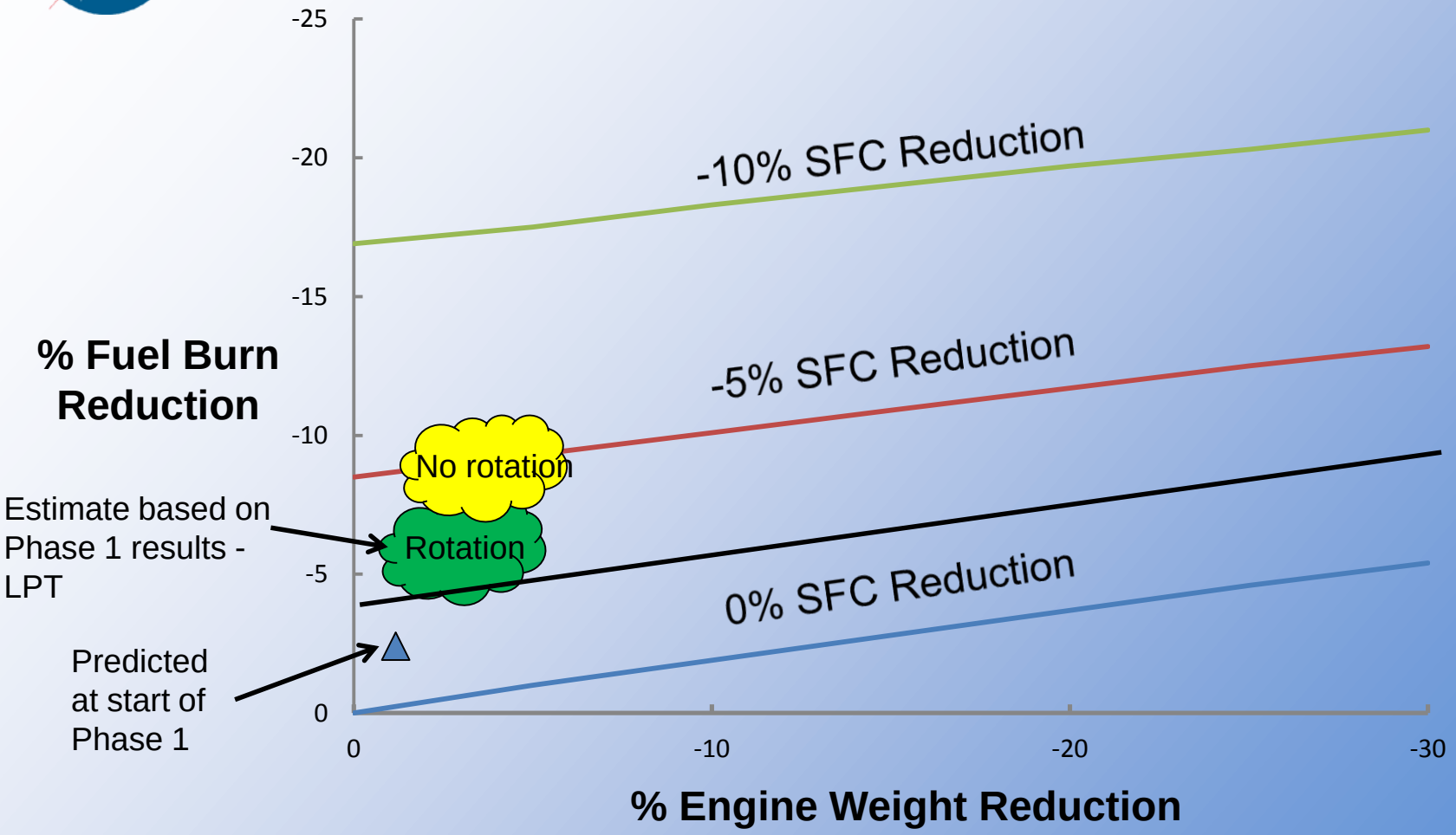


Circumstantial Evidence



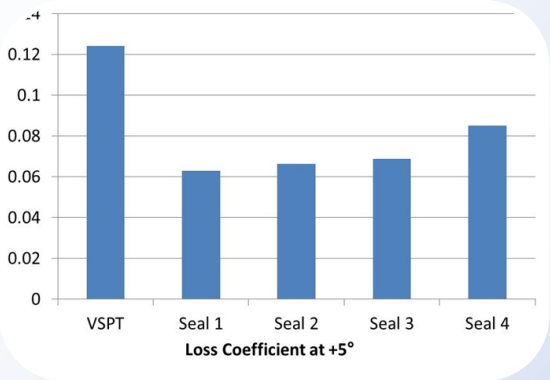


Possible reduction in broadband noise

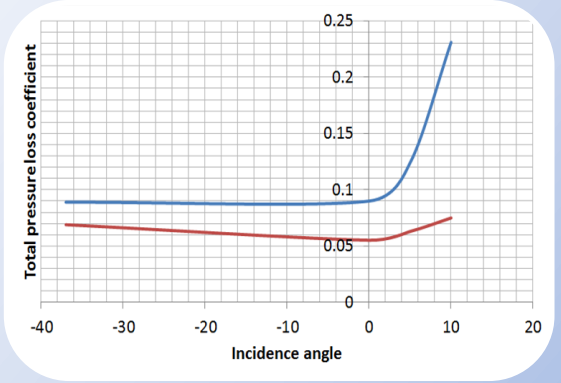


» This was previous work for a 300 PAX aircraft
» Benefits might be slightly lower for N2A (767 class) aircraft

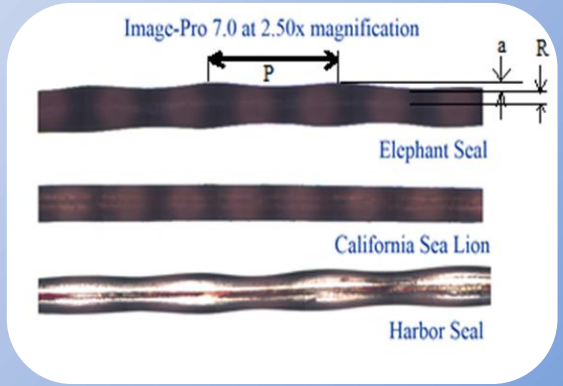
Conclusions



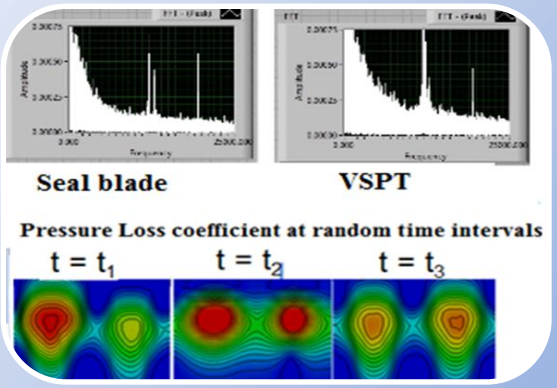
Bio-inspired blade showed 50% drag reduction over baseline

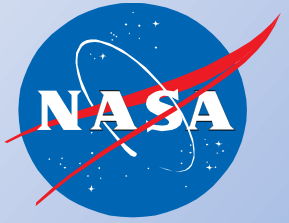


Blades treated with the Seal Vibrissa–like undulations were shown to be insensitive to incidence change



Blade with seal whisker LE parameters showed best results



Possible benefits to noise reduction

Several other applications could benefit more directly